Intensive Care Med
https://doi.org/10.1007/s00134-025-07840-1

CONFERENCE REPORTS AND EXPERT PANEL

European Society of Intensive Care Medicine (ESICM) 2025 clinical practice guideline on fluid therapy in adult critically ill patients: part 2—the volume of resuscitation fluids

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Abstract

Objective: This European Society of Intensive Care Medicine (ESICM) guideline provides evidence-based recommendations on the volume of early resuscitation fluid for adult critically ill patients.

Methods: An international panel of experts developed the guideline, focusing on fluid resuscitation volume in adult critically ill patients with circulatory failure. Using the PICO format, questions were formulated, and the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach was applied to assess evidence and formulate recommendations.

Results: In adults with sepsis or septic shock, the guideline suggests administering up to 30 ml/kg of intravenous crystalloids in the initial phase, with adjustments based on clinical context and frequent reassessments (very low certainty of evidence). We suggest using an individualized approach in the optimization phase (very low certainty of evidence). No recommendation could be made for or against restrictive or liberal fluid strategies in the optimization phase (moderate certainty of no effect). For hemorrhagic shock, a restrictive fluid strategy is suggested after blunt trauma (moderate certainty) and penetrating trauma (low certainty), with fluid administration for non-traumatic hemorrhagic shock guided by hemodynamic and biochemical parameters (ungraded best practice). For circulatory failure due to left-sided cardiogenic shock, fluid resuscitation as the primary treatment is not recommended. Fluids should be administered cautiously for cardiac tamponade until definitive treatment and guided by surrogate markers of right

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The members of the "European Society of Intensive Care Medicine" is present in the electronic supplementary material.

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heart congestion in acute pulmonary embolism (ungraded best practice). No recommendation could be made for circulatory failure associated with acute respiratory distress syndrome.

Conclusions: The panel made four conditional recommendations and four ungraded best practice statements. No recommendations were made for two questions. Knowledge gaps were identified, and suggestions for future research were provided.

Keywords: Shock, Fluid therapy, Volume, Liberal, Restrictive, Individualization, Practice guidelines, Critical care

Introduction

The administration of resuscitation fluids is common in the management of critically ill patients. The European Society of Intensive Care Medicine (ESICM) convened a group of content and methods experts to produce a clinical practice guideline (CPG) on fluid management in adult critically ill patients. This CPG was divided into three parts: the type of resuscitation fluids (Part 1), the volume of resuscitation fluids (Part 2), and fluid removal in the de-escalation phase (Part 3). The full contributors are presented in the electronic supplementary material. In this manuscript, the guideline on the volume of resuscitation fluid is presented.

Resuscitation fluids are typically given as a bolus or challenge during circulatory failure. The primary goal of fluid therapy is to increase stroke volume and cardiac output to increase systemic blood flow and tissue perfusion. In clinical practice, the volume of resuscitation fluids may vary depending on the pathophysiology of circulatory failure, clinician preference, and practice setting.

The aim of this ESICM guideline was to provide evidence-based guidance on the volume of resuscitation fluid in adult critically ill patients, supported by a critical analysis of the literature.

Take-home message

In adults with sepsis or septic shock, we suggest to administer up to 30 ml/kg of intravenous crystalloids in the initial phase, with adjustments based on clinical context and frequent reassessments, and to use an individualized approach in the optimization phase. We were unable to make a recommendation for or against systematic restrictive or liberal fluid administration in the optimization phase.

In adults with hemorrhagic shock, we suggest a restrictive fluid resuscitation strategy (as part of a permissive hypotension approach) after blunt or penetrating trauma, and we recommend (best practice statement) to guide fluid administration by hemodynamic and biochemical parameters for hemorrhagic shock of non-traumatic origin.

We recommend (best practice statement) against the use of fluid resuscitation as the primary treatment for circulatory failure due to left-sided cardiogenic shock, for the cautious administration of fluids as a temporary measure until definitive treatment can be given for circulatory failure due to cardiac tamponade, and for the cautious administration of fluids with clinical decisions based on measured surrogate markers of right heart congestion for circulatory failure due to pulmonary embolism.

We were unable to make a recommendation for circulatory failure associated with acute respiratory distress syndrome.

Methods

Guideline scope and target audience

The purpose of this guideline is to provide evidence-based guidance on the volume of fluid resuscitation in adult critically ill patients with circulatory failure due to a variety of causes. The target audience for this guideline is frontline clinicians (physicians and nurses), allied health professionals, and policy-makers in high-, low-, and middle-income countries.

Panel selection and organization

Panel members were appointed with diversity and inclusivity in mind as previously described [1]. The panel consisted of two ESICM guideline co-chairs, a clinical chair, a methods chair, two methodologists and 13 clinical experts, including methodologists and clinicians specialized in critical care, emergency medicine, and anesthesia.

Conflict of interest management

We applied the principles of conflict of interest management as previously described [2]. Panelists were asked to declare any intellectual or financial conflict of interest (COI) that might influence their participation in the guideline, by completing a specific form in accordance with ESICM procedures. A summary of individual declarations can be found at the end of the document under the COI section. Panelists received no financial incentives for their participation. In addition, no funding or input from industry was incorporated into the guideline.

Development of questions and outcomes selection

This guideline addressed the volume of resuscitation fluid in adult critically ill patients with circulatory failure of various etiologies. One question addressed patients with circulatory failure and acute respiratory distress syndrome. Studies on the intraoperative setting, maintenance fluid, fluid volume for burn management, or management of increased intracranial pressure were excluded.

Population, Intervention, Comparison, and Outcomes (PICO) questions were proposed, prioritized, and approved by all panelists. The guideline included recommendations for ten questions covering the following areas (A) sepsis (three questions, in the initial and optimization phases); (B) hemorrhagic shock (three questions, for penetrating trauma, blunt trauma and non-traumatic causes), (C) obstructive shock (two questions, for pulmonary embolism and cardiac tamponade), (D) left-sided cardiogenic shock (one question) and (D) acute respiratory distress syndrome (one question).

The panelists selected and prioritized patient-centered outcomes for each PICO on a scale of 1 to 9 (from not important to critical) [8]. The following outcomes were considered critical: short-term mortality, need for renal replacement therapy, ventilator-free days/duration of mechanical ventilation, intensive care unit (ICU)-free days/ICU length of stay, hospital-free days/hospital length of stay, quality of life, and functional outcomes. The panel carefully deliberated the importance of outcomes throughout the process, from reviewing the evidence to formulating the recommendation [3].

Literature search

The methodologists searched for relevant systematic reviews and meta-analyses and updated them as necessary. If neither was available, we searched MEDLINE & EMBASE from inception to June 2022 for randomized clinical trials (RCTs). Search profiles are available in the electronic supplementary material.

Data analysis

The DerSimonian and Laird random effects model was used to pool results of effect sizes across RCTs [4, 5]. Relative risks (RRs) with corresponding 95% confidence intervals (CIs) were used for binary outcomes, while mean differences (MDs) and 95% CIs were used for continuous outcomes. The I^2 statistics was used for descriptive rather than inferential purposes, and heterogeneity was assessed primarily on a clinical basis. All analyses were performed using Review Manager (RevMan) version 5.4, The Cochrane Collaboration, 2000 [5].

Risk of bias and overall certainty of evidence

The Cochrane Collaboration Risk of Bias (ROB) 1.0 tool was used to assess the risk of bias of individual RCTs. The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) methodology was used to assess the certainty of the evidence [6]. The certainty of evidence from RCTs for each critical outcome starts with a high rating, but can be lowered by one or two points for each of the following domains: risk of bias, inconsistency, indirectness, imprecision, and publication bias [7]. The certainty of the evidence for each recommendation was determined based on the panel's deliberations, considering the totality of the evidence, including the level of certainty for the critical outcome with the lowest certainty [8]. For each PICO, we report the level of certainty and the areas involved in the downgrading in the relevant Summary of Evidence section and provide a more detailed description in the Evidence Profile tables in the electronic supplementary material. The GRADEpro GDT (GRADEpro Guideline Development Tool [Software], McMaster University and Evidence Prime, 2022 available from www.gradepro.org was used to generate evidence profiles for each PICO. The evidence profiles included all prioritized outcomes for which data were identified during the literature search.

Recommendation formulation

The panel met monthly online and used the Evidence-to-Decision (EtD) framework to formulate recommendations [9]. As described in the GRADE methodology, the panel considered the following factors in deciding the direction and strength of recommendations: magnitude of effect, certainty of evidence, patient values and preferences, resources and costs, equity, acceptability and feasibility. For a strong recommendation, we used the phrase "we recommend", and for a conditional recommendation (also called a weak recommendation), we used the phrase "we suggest". A strong recommendation in favor of an intervention means that the desirable benefits of the intervention outweigh any significant adverse effects, that most patients and clinicians would choose the recommendation, and that it can be adopted as policy. On the other hand, a conditional recommendation in favor of an intervention means that the desirable benefit of the intervention outweighs the undesirable effect, but with low confidence. It means that a majority, but not all, people are likely to be best served by the recommended intervention [9]. It also implies that most patients and clinicians would accept the proposed action of a conditional recommendation, but a significant number would not, and for policy-makers, it would not be appropriate to adopt it as policy. To provide practical guidance to critical practitioners, we presented recommendations in favor of one approach rather than against an alternative [10]. The panel used consensus to formulate recommendations and all members approved the final recommendations.

Results

A. Sepsis

Question 1

Should 30 ml/kg fluid volume be used versus other approaches for initial resuscitation of circulatory

Table 1 Summary of clinical questions and recommendations for sepsis

Question and recommendation		Recommendation strength	Certainty of evidence
Question 1	Should 30 ml/kg fluid volume be used versus other approaches for initial resuscitation of circulatory failure in critically ill patients with sepsis or septic shock?		
Recommendation	*In adults with sepsis or septic shock who require fluid resuscitation for circulatory failure, we suggest administering up to 30 ml/kg of intravenous crystalloids in the initial phase (when hemodynamic monitoring is not yet available, typically within the first 3 h), with adjustments based on clinical context and frequent reassessments*	*Conditional Recommendation, For*	*Very Low certainty of evidence*
Remark	*Clinicians may choose to administer different volumes of crystalloids based on their clinical judgment, individual patient characteristics and clinical context,* such as the origin of sepsis (e.g., lung versus abdomen), cardiovascular comorbidities, or the presence or not of fluid losses		
Remark	*Clinicians should assess their patients clinically and consider assessing fluid responsiveness (if possible) before administering more crystalloids in the initial phase of resuscitation, recognizing that some may require more or less than 30 mL/kg of intravenous crystalloids*		
Question 2	Should a liberal vs. restrictive strategy be used in the optimization phase of resuscitation of circulatory failure in critically ill patients with sepsis or septic shock?		
Recommendation	*In adults with sepsis or septic shock who need fluid resuscitation for circulatory failure, we cannot recommend for or against systematic restrictive or liberal fluid administration*	*No recommendation*	*Moderate Certainty of evidence*
Remark	*In randomized trials, the use of a systematic restrictive strategy versus a systematic liberal strategy in the optimization phase of resuscitation had similar effects on patient-relevant outcomes (moderate certainty of evidence)*		
Question 3	Should an individualized approach vs a non-individualized approach be used for the optimization phase of resuscitation of circulatory failure in critically ill patients with sepsis or septic shock?		
Recommendation	*In adults with sepsis or septic shock who require fluid resuscitation for circulatory failure, we suggest using an individualized approach compared with a non-individualized approach during the optimization phase*	*Conditional recommendation, For*	*Very low certainty of evidence*

failure in critically ill patients with sepsis or septic shock? (Table 1).

Background Fluid resuscitation remains a cornerstone of septic shock management. The conceptual framework of fluid therapy for sepsis includes four phases. It begins with rapid initial resuscitation, moves on to the optimization of organ and tissue perfusion, is followed by a phase of physiological stabilization, and concludes with the recovery phase [11]. The initial phase is the salvage phase, during which the patient is first identified as being in shock and no hemodynamic monitoring is applied. The optimization phase follows, involving the assessment of the patient using various monitoring techniques [12]. In most studies on septic shock resuscitation, the initial phase generally covers the first 1 to 6 h of treatment. The timing of this transition can vary based on the organization and resources of different centers but is typically completed within 3 h in high-income countries. Since the first version of the Surviving Sepsis Campaign (SSC) guidelines, the administration of fluid resuscitation has been part of the initial resuscitation package for patients with septic shock and may be associated with improved survival [13]. However, the volume of fluid to be administered during initial fluid resuscitation remains controversial [14]. The SSC guidelines suggest an initial dose of at least 30 mL/kg of crystalloids to be administered within the first 3 h of resuscitation. The choice of a fixed dose of 30 mL/kg from the SSC is somewhat arbitrary and based only on observational data [13, 15–17] and has been questioned by some authors and trials [18, 19]. In addition, several observational studies have suggested possible harm from cumulative positive fluid balance in septic patients [20–22]. Finally, the safety and the efficacy of a fixed dose of 30 mL/kg of fluid in patients at high risk of fluid overload

(e.g., patients with heart failure or chronic kidney disease requiring dialysis) remain unclear [23–25].

Summary of evidence A recent systematic review and meta-analysis of RCTs with pre-planned separation of intravenous fluid volumes or balances did not identify any RCT that specifically addressed the volume of 30 ml/kg versus other volumes [26]. Our updated search did not identify any additional RCTs. Therefore, there is currently no evidence from RCTs to support or discourage the administration of 30 ml/kg crystalloids (or any other volume) as initial resuscitation in patients with sepsis-associated hypoperfusion or septic shock.

According to recent RCTs investigating resuscitation strategies in septic shock, current practice for initial resuscitation appears to be to administer a mean/median initial volume of 1 to 3 L of crystalloids, or 20–35 mL/kg, within 3–6 h. However, this practice is associated with wide variability (lowest quartile: 500 mL, highest quartile: 5 L) (see additional references in the electronic supplementary material). In particular, most trials required at least 1 L of fluid to be administered as an inclusion criterion, with some requiring at least 30 mL/kg.

Recent RCTs conducted in high-income countries evaluating different fluid management strategies after initial resuscitation in septic patients showed no harm within the ranges of fluid volumes tested (the median difference between the restrictive and liberal groups at 24 h in the CLASSIC and CLOVERS trials was − 800 mL (500 mL vs. 1313 mL) and − 2100 mL (1267 mL vs. 3400 mL), respectively) [27, 28]. Hypothesis-generating pre-planned subgroup analyses of the CLASSIC trial suggested that patients who had received an initial volume < 30 mL/kg showed a trend toward benefiting from a subsequent liberal strategy (absolute percentage point difference in 90-day mortality [95% CI] = 5.3 [− 3.1 to 13.5]; p-value for interaction = 0.15) and vice versa [28].

A single RCT in a low-income country comparing a protocol-based initial resuscitation strategy (including a fixed volume of up to 4 L of fluid) with standard care (resuscitation strategy decided by the attending physicians) found higher mortality with protocol-based care (including a median of 3.5 [2.7–4] liters of fluid in 6 h) [29]. Patients in the standard care group received a median of 2 L (1–2.5) of fluid in 6 h. It should be noted that a fixed volume of fluids was administered, which meant that patients with lower body weight, such as those who were malnourished, received a higher volume of fluids per kilogram of body weight. Furthermore, as this trial investigated a protocol-based strategy, we cannot differentiate the effect of the different elements of the protocol on the outcome. An RCT in pediatric patients with febrile illness and signs of hypoperfusion in low-income countries found higher mortality in patients who received a fluid bolus of 20 to 40 ml/kg over 1 h compared with patients who received no bolus (median 20 ml/kg in the first hour in both intervention groups, i.e., albumin and saline vs 1.2 mL/kg in the no fluid bolus group, and median 40 mL/kg in both interventional groups in the first 8 h vs. 10 mL/kg in the no fluid bolus group) [30]. A recent meta-analysis reported that the effect of the fluid resuscitation approach differed by setting, with higher volumes of fluid resuscitation associated with increased mortality in LMICs and in settings with limited access to mechanical ventilation [31]. These differences may not be generalizable to all LMICs, and the exact reason for them is unclear and may in part be due to resource constraints, participant variation between trials, or other unmeasured factors [31]. However, they may suggest caution when using large volumes of fluids in contexts similar to these trials, where immediate access to additional monitoring and support systems (e.g., pulse oximetry, supplemental oxygen, ventilatory support) is limited [31].

Observational studies conducted in high-risk populations (congestive heart failure, chronic kidney disease, cirrhosis) have found conflicting results, with some suggesting improved outcomes with lower volume resuscitation (i.e. < 30 mL/kg) [24, 32, 33] and others finding no signal of harm with standard volume resuscitation (≥ 30 mL/kg) [34–37].

Panel discussions emphasized that clinical characteristics, such as the origin of sepsis (e.g., lung vs. abdomen), cardiovascular comorbidities, and the presence or absence of fluid losses, may help identify patients who are more likely to have significant volume deficits or poorer fluid tolerance.

Recommendation In adults with sepsis or septic shock who require fluid resuscitation for circulatory failure, we suggest administering up to 30 ml/kg of intravenous crystalloids in the initial phase (when hemodynamic monitoring is not yet available, typically within the first 3 h), with adjustments based on clinical context and frequent reassessments (conditional recommendation, very low certainty of evidence).

Remark Clinicians may choose to administer different volumes of crystalloids based on their clinical judgment, individual patient characteristics and clinical context, such as the origin of sepsis (e.g., lung versus abdomen), cardiovascular comorbidities, or the presence or not of fluid losses.

Clinicians should assess their patients clinically and consider assessing fluid responsiveness (if possible) before administering more crystalloids in the initial phase

of resuscitation, recognizing that some may require more or less than 30 mL/kg of intravenous crystalloids.

Unresolved questions and research gaps Several questions about initial resuscitation remain unanswered. RCTs are needed to assess the safety and efficacy of initial resuscitation with 30 mL/kg crystalloids compared with other approaches (e.g., lower volume resuscitation, individualized approach, vasopressor first approach) in patients with sepsis and hypoperfusion as there is currently no high-certainty of evidence to support any approach. The application of the same strategy in different settings (high- versus low-income countries) may lead to different outcomes, depending on factors that are still unclear, such as different patient characteristics, different etiologic agents, availability of "rescue" strategies to treat possible complications, and this warrants further investigation.

Question 2

Should a liberal vs. restrictive strategy be used in the optimization phase of resuscitation of circulatory failure in critically ill patients with sepsis or septic shock?

Background The risk associated with fluid accumulation or overload during sepsis has been highlighted by several observational studies over the past decades [38]. Fluid overload could increase the risk of organ dysfunction and death. Despite this, it is still unclear whether a restrictive or liberal intravenous fluid strategy should be used. In fact, the 2021 SSC guidelines found that there was insufficient evidence to recommend the use of restrictive versus liberal fluid strategies in the first 24 h of resuscitation in patients with sepsis or septic shock who still have signs of hypoperfusion and volume depletion after initial resuscitation; this lack of recommendation was due to very low-certainty of evidence [13].

Summary of evidence Physiological rationale and observational data provide some support for a strategy of lower fluid volumes combined with earlier initiation of vasopressors during sepsis [39, 40]. However, current evidence from RCTs does not support the use of either exclusively liberal or restrictive fluid administration. Two recent meta-analyses have been reviewed to address this issue [26, 41]. The most recent meta-analysis [26] included 13 RCTs with 4,006 patients [27, 28, 42–52]. There was no difference in mortality between the two strategies: risk ratio (RR) 0.99, 97% confidence interval (CI) 0.89, 1.08; $p=0.69$; moderate certainty of evidence. Serious adverse events (SAEs) were defined and reported in six trials and showed no difference between the two strategies: RR of 0.95 (97% CI 0.83, 1.07; $p=0.28$; low certainty of evidence). Seven trials reported the duration of mechanical ventilation and 10 trials assessed ventilator-free days, with no significant difference between groups. For the latter, five trials had a low risk of bias (3354 patients) with an RR of 0.99 (CI 1.89, 1.67; $p=0.87$). There was also no significant difference between groups in vasopressor-free days, use or duration of renal replacement therapy, or acute kidney injury. No relevant subgroup effects were observed. The CLASSIC [28] and CLOVERS [27] trials contributed with most patients in this meta-analysis (3385 of 4006) [26]. In the CLASSIC trial [28], the median cumulative fluid volume of all fluids given in the ICU was relatively high in both groups (10,433 mL in the restrictive fluid group and 12,747 mL in the standard-fluid group), which may have attenuated the potential effect of the intervention.

Recommendation In adults with sepsis or septic shock who need fluid resuscitation for circulatory failure, we cannot recommend for or against systematic restrictive or liberal fluid administration (no recommendation; moderate level of evidence for no effect).

Remark In RCTs, the use of a systematic restrictive strategy versus a systematic liberal strategy in the optimization phase of resuscitation had similar effects on patient-relevant outcomes (moderate certainty of evidence).

Unresolved questions and research gaps Several ongoing trials are trying to answer this question using different approaches [53]. The volume of fluid administered during the resuscitation phase of sepsis and septic shock appears to have decreased over time, making trial design more difficult to detect differences between groups. Efforts to better assess heterogeneity in treatment effects and to better monitor perfusion signals for potential harm in restrictive or liberal arms are advisable.

Question 3

Should an individualized approach vs a non-individualized approach be used for the optimization phase of resuscitation of circulatory failure in critically ill patients with sepsis or septic shock?

Background Individualization of fluid administration in sepsis or septic shock during the optimization phase should include monitored fluid administration via fluid boluses aimed at improving preload/systemic blood flow and consequently reversing tissue hypoperfusion. Individualization requires some form of hemodynamic monitoring and is usually performed in ICU, with the aim not of restricting fluid but of administering it more optimally. Some key measures to individualize fluid administration may be the use of the fluid challenge approach [54], systematic fluid responsiveness assessment [55], considera-

tion of basic hemodynamic phenotypes (e.g., vasoplegic vs persistently hypovolemic patients) [53], and selection of the most appropriate target to stop resuscitation in a timely manner to reduce the risk of fluid overload [56].

Assessment of fluid responsiveness may be an important part of this monitoring and, the first data have been published on its potential impact on some secondary outcomes [51] and on reducing fluid volume (in fluid unresponsive patients) without compromising perfusion [55]. Of note, in the latter study, 30% of patients in whom fluid responsiveness could be assessed were already fluid unresponsive shortly after admission to the ICU, but still achieved resuscitation goals with vasoactive-driven strategies [55].

Several studies of varying quality have shown that perfusion-related targets, such as lactate, central venous oxygen saturation, arterio-venous gradient of carbon dioxide, or peripheral perfusion, show different dynamics of recovery after restoration of systemic blood flow or perfusion pressure [56]. Some recover very quickly, such as capillary refill time, while others, such as lactate, are still abnormal in 50% of survivors after 24 h [56]. Selecting a particular perfusion variable as a target may therefore be associated with a different intensity of fluid resuscitation. This may influence the volume of fluid given and potentially the outcome.

Summary of evidence Eight RCTs compared the use of fluid responsiveness assessment with usual care in sepsis resuscitation [42, 45, 49, 51, 57–60]. The trials were highly heterogeneous in terms of inclusion criteria, definitions of fluid responsiveness, monitoring, fluid administration algorithm and outcomes. Short-term mortality was assessed in 363 patients in the intervention arm vs. 321 in the control arm, with 83 vs. 95 deaths, respectively (RR 0.82, 95% CI 0.63, 1.07, I^2 10%, $p=0.14$). Four RCTs analyzed ventilator-free days in 128 vs 131 patients with no difference between groups (mean difference −0.33, 95% CI −2.65, 2). There was also no difference in vasopressor-free days in one trial, similar to 3 trials analyzing renal replacement therapy in 173 vs. 129 patients, with 36 vs. 44 events (RR 0.69, 95% CI 0.38, 1.24, I^2 56%, $p=0.21$). No trials comparing a perfusion-targeted strategy with usual care were identified.

Based on the scarce and heterogeneous evidence available, the panel issued a conditional recommendation for individualized resuscitation vs. a non-individualized approach during the optimization phase based on very low certainty of evidence.

Recommendation In adults with sepsis or septic shock who require fluid resuscitation for circulatory failure, we suggest using an individualized approach compared with a non-individualized approach during the optimization phase (conditional recommendation, very low certainty of evidence).

Unresolved questions and research gaps Given the limited data available, further research is urgently needed to establish the role of systematic assessment of fluid responsiveness, specific targets and hemodynamic phenotype-driven resuscitation strategies, among others, in sepsis or septic shock. These trials should be better designed and adequately powered, considering more homogeneous populations and overcoming the enormous challenges of testing individualized algorithms versus usual care [53].

Hemorrhagic shock

Question 4

Should a restrictive or liberal strategy be used for fluid resuscitation of circulatory failure in critically ill patients with hemorrhagic shock following penetrating trauma? (Table 2)

Background Penetrating trauma accounts for 12–18% of all trauma in the United States and is associated with a significantly higher mortality rate than other types of trauma. Rapid control of hemorrhage and restoration of tissue perfusion are the cornerstones of the management of penetrating trauma-induced hemorrhagic shock. However, the delicate balance between restoring perfusion and avoiding complications from inappropriate fluid resuscitation requires careful consideration. The concept of a permissive approach to hypotension by the restrictive fluid resuscitation strategy in hemorrhagic shock secondary to penetrating trauma has been proposed [61, 62]. Maintaining a lower blood pressure may slow the rate of bleeding, particularly from arterial sources. In addition, lower blood pressure reduces the hydrostatic pressure in the injured vessels, which may prevent the dislodgement of formed hemostatic clots and reduce hemorrhage. In addition, limiting the volume of resuscitation fluids may prevent dilutional coagulopathy and mitigate hypothermia. While we recognize the importance of RBCs and plasma in the management of hemorrhagic shock, this topic falls outside the scope of the guideline.

Summary of evidence The most recent evidence comes from an updated meta-analysis (which includes three trials and 831 patients with penetrating trauma) finding a reduction in mortality with permissive hypotension in cases of hemorrhagic shock (RR = 0.80; 95% CI [0.65, 0.90]) [63–65]. However, the quality of the evidence is low due to the limited number of trials included in the analysis. The fluid resuscitation endpoint was maintained at a systolic blood pressure of around 80–90 mmHg, or a

Table 2 Summary of clinical questions and recommendations for hemorrhagic shock

Question and recommendation		Recommendation strength	Certainty of evidence
Question 4	Should a restrictive or liberal strategy be used for fluid resuscitation of circulatory failure in critically ill patients with hemorrhagic shock following penetrating trauma?		
Recommendation	*In adults with hemorrhagic shock after penetrating trauma, we suggest using a restrictive fluid resuscitation strategy (as part of a permissive hypotension approach) compared with a liberal fluid resuscitation strategy prior to definitive hemorrhage control*	*Conditional recommendation, For*	*Moderate Certainty of evidence*
Remark	*This recommendation does not apply to the intraoperative management of these patients. In patients with penetrating trauma and associated traumatic brain injury, there are insufficient data to make a recommendation*		
Question 5	Should a restrictive or liberal strategy be used for fluid resuscitation of circulatory failure in critically ill patients with hemorrhagic shock following blunt trauma?		
Recommendation:	*In adults with hemorrhagic shock following blunt trauma, we suggest a restrictive fluid resuscitation strategy (as part of a permissive hypotensive approach) compared with a liberal fluid resuscitation strategy before definitive hemorrhage control*	*Conditional recommendation, For*	*Low Certainty of evidence*
Remark	*This recommendation does not apply to the intraoperative management of these patients. In patients with blunt trauma and associated traumatic brain injury, there is insufficient data to make a recommendation*		
Question 6	Should a restrictive or liberal strategy be used for fluid resuscitation of circulatory failure in critically ill patients with hemorrhagic shock of non-traumatic origin?		
Recommendation:	*The panel recommends (ungraded best practice statement) that in adults with hemorrhagic shock of non-traumatic origin, fluid administration should be guided by hemodynamic and biochemical parameters in the context of the primary disease state prior to definitive hemorrhage control*	*Best Practice Statement*	*Ungraded*
Remark	*The biochemical parameters that the clinician should aim to correct include metabolic acidosis, hypothermia, platelet counts and coagulation factors*		

mean arterial pressure of 50–60 mmHg [66]. Of note, the Bickell et al. trial [63] contributed to 72% of the weight for the mortality outcome. As such, newer evidence is needed to advance the field, given the significant changes in the trauma care landscape since the trial's publication in 1994.

Recommendation In adults with hemorrhagic shock after penetrating trauma, we suggest using a restrictive fluid resuscitation strategy (as part of a permissive hypotension approach) compared with a liberal fluid resuscitation strategy prior to definitive hemorrhage control (conditional recommendation, moderate certainty of evidence).

Remark This recommendation does not apply to intraoperative management of these patients or after definitive hemorrhage control. In patients with penetrating trauma and associated traumatic brain injury, there are insufficient data to make a recommendation.

Unresolved questions and research gaps The current evidence on low volume fluid resuscitation in trauma is limited, indicating a need for more large-scaled, well-designed RCTs to assess its effectiveness. Critical questions remain unanswered: the specific systolic blood pressure target, the recommended duration for permissive hypotension, and alternative indicators for central and cerebral perfusion when blood pressure readings are unreliable or unavailable. Additionally, it is important to explore whether individualized approaches, based on factors like age, comorbidities, and injury severity, lead to better outcomes.

Question 5

Should a restrictive or liberal strategy be used for fluid resuscitation of circulatory failure in critically ill patients with hemorrhagic shock following blunt trauma?

Background Blunt trauma is caused by direct physical trauma or impact to a part of the body. It is common in

road traffic collisions, assaults and sports injuries and is particularly common in older people who fall. Blunt trauma can occur in the abdomen, chest, skull, pelvis and extremities. Theoretical frameworks and experimental evidence do not provide a basis for distinguishing blunt injuries from other types of trauma [67].

Summary of evidence Both penetrating and blunt trauma require immediate hemostasis and fluid resuscitation to control blood loss and tissue perfusion. Permissive hypotension is commonly used in both scenarios [68]. In blunt trauma without traumatic brain injury, a systolic blood pressure target of around 80–90 mmHg or a mean arterial pressure of 50–60 mmHg may be required [66]. However, in blunt trauma with traumatic brain injury, the target systolic blood pressure may be around 100–110 mmHg or a mean arterial pressure of at least 80 mmHg to ensure adequate cerebral perfusion pressure and prevent secondary brain injury [13, 66]. We found only two RCTs included mixed trauma types (penetrating and blunt trauma) [69, 70], so a meta-analysis of permissive hypotension or limited fluid resuscitation in blunt trauma could not be performed. However, the above-mentioned meta-analysis indicated that permissive hypotension was protective in patients with hemorrhagic shock in general.

Recommendation In adults with hemorrhagic shock following blunt trauma, we suggest a restrictive fluid resuscitation strategy (as part of a permissive hypotensive approach) compared with a liberal fluid resuscitation strategy before definitive hemorrhage control (conditional recommendation, for; low certainty of evidence).

Remark This recommendation does not apply to intraoperative management of these patients or after definitive hemorrhage control. In patients with blunt trauma and associated traumatic brain injury, there is insufficient data to make a recommendation.

Unresolved questions and research gaps First, all the unresolved questions and research gaps mentioned for penetrating trauma apply to this question. As traumatic brain injury from blunt trauma is more common than from penetrating trauma, trials on the ideal blood pressure for traumatic brain injury are needed. Future trials should also assess whether there are differences in blood pressure targets for specific subtypes of blunt trauma (e.g., chest, abdominal or pelvic blunt trauma). The evidence gap for intraoperative fluid management in these patients also needs to be addressed.

Question 6

Should a restrictive or liberal strategy be used for fluid resuscitation of circulatory failure in critically ill patients with hemorrhagic shock of non-traumatic origin?

Background Non-traumatic hemorrhagic shock can be caused by factors such as gastrointestinal bleeding or post-operative hemorrhage or ruptured aneurysm, where the primary concern is blood loss rather than tissue injury. Conservative approaches with low volume/restrictive fluid resuscitation and blood pressure management may be useful in some cases to avoid surgery. Fluid resuscitation with permissive hypotension may also be applied in the management of non-traumatic hemorrhagic shock. However, the target blood pressure is influenced by the primary etiology of the hemorrhage and requires a nuanced approach that takes into account the specific disease state of the patient [71–74].

Summary of evidence A study of 51 patients by Lu et al. found that conservative fluid resuscitation was beneficial in patients with hemorrhagic shock due to acute upper gastrointestinal hemorrhage [75]. The use of vasopressors in non-traumatic hemorrhagic shock is controversial. They can be used to support blood pressure, particularly if fluid resuscitation is inadequate. However, their early administration in high doses has been associated with increased mortality [76]. An RCT of 249 patients found that restrictive fluid resuscitation had no significant effect on thromboelastometric hemostatic and coagulation parameters in women with postpartum hemorrhage < 1500 mL [77]. In patients with non-traumatic hemorrhagic shock, several conditions should be corrected, including metabolic acidosis, hypothermia, and coagulopathy.

Recommendation The panel recommends (ungraded best practice statement) that in adults with hemorrhagic shock of non-traumatic origin, fluid administration should be guided by hemodynamic and biochemical parameters in the context of the primary disease state prior to definitive hemorrhage control.

Remark The biochemical parameters that the clinician should aim to correct include metabolic acidosis, hypothermia, platelet counts, and coagulation factors.

Unresolved questions and research gaps Several areas warrant further investigations: defining specific hemodynamic and biochemical thresholds for different etiologies of non-traumatic hemorrhagic shock; assessing functional recovery of organ function and quality of life in addition to mortality; evaluating the impact of early intervention (e.g., within the first 6 h) on outcomes.

Table 3 Summary of the clinical question and recommendation for obstructive shock

Question and recommendation		Recommendation strength	Certainty of evidence
Question 7	Should a restrictive or liberal strategy be used for fluid resuscitation of circulatory failure in critically ill patients with pulmonary embolism?		
Recommendation:	*The panel recommends (ungraded best practice statement) that in adult patients with circulatory failure due to acute pulmonary embolism, clinicians should be cautious about administering fluids and should base their decision on measured surrogate markers of right heart congestion*	*Best Practice Statement*	*Ungraded*
Question 8	Should a restrictive or liberal strategy be used for fluid resuscitation of circulatory failure in critically ill patients with cardiac tamponade?		
Recommendation:	*The panel recommends (ungraded best practice statement) that in adult patients with circulatory failure due to cardiac tamponade, fluid should be given cautiously as a temporary measure until definitive management can be undertaken*	*Best Practice Statement*	*Ungraded*

Obstructive shock

Question 7

Should a restrictive or liberal strategy be used for fluid resuscitation of circulatory failure in critically ill patients with pulmonary embolism? (Table 3)

Background The major cause of death in patients with massive acute pulmonary embolism is circulatory failure. De-obstruction of the pulmonary circulation (primarily by thrombolytic therapy) is the mainstay of treatment for circulatory failure, but hemodynamic support is essential before substantial hemodynamic improvement is achieved [78]. The use of fluid resuscitation in intermediate and high-risk pulmonary embolism remains controversial. The European Society of Cardiology guidelines suggest that modest fluid resuscitation may be given if central venous pressure is low [79], but there is a risk of worsening right ventricular function. This concern has recently been re-emphasized in the specific population of ICU patients with pulmonary embolism [80].

Summary of evidence Nine studies (4 animal, 5 human) were identified [78, 81–88]. The human literature included 456 patients, with only one study (13 patients) including patients in shock (cardiac index < 2.5 L/min/m^2) [78]. In the latter study [78], a fluid bolus (dextran 500 mL) was administered as part of the intervention. The increase in cardiac index induced by fluid loading was inversely related to the baseline right ventricular end-diastolic volume index [78].

The other 4 human trials in patients without shock used a diuretic as the intervention and either placebo (one trial) [84] or a saline fluid bolus (three trials) [83, 87, 88] as the control. The diuretic was well tolerated [83, 84, 87, 88], with some beneficial effects on surrogate markers [83, 84, 87], including reduction in shock index, oxygen requirements and plasma creatinine [88]. Taken together, these findings suggest that fluid resuscitation in patients with pulmonary embolism and shock may not be beneficial in the presence of severe right heart congestion. The latter can be detected using various surrogate markers, such as central venous pressure (if greater than 10 mmHg), echocardiography (if right ventricular size is greater than left ventricular size), VEXUS (if greater than grade 1), among others. In resource-limited settings, the use of a clinical examination to determine congestion may be used as a surrogate marker (e.g., jugular venous pressure, hepatomegaly). Fluids should probably be avoided in these circumstances, especially when combined. However, the uncertainty in this area is very high.

Recommendation The panel recommends (ungraded best practice statement) that in adult patients with circulatory failure due to acute pulmonary embolism, clinicians should be cautious about administering fluids and should base their decision on surrogate markers of right heart congestion.

Unresolved questions and research gaps There is insufficient evidence to support either a liberal or restrictive intravenous fluid strategy in patients with circulatory failure due to pulmonary embolism. Most publications focus on patients with intermediate-risk pulmonary embolism without shock. RCTs are needed in patients with shock with detailed phenotyping of right heart congestion.

Question 8

Should a restrictive or liberal strategy be used for fluid resuscitation of circulatory failure in critically ill patients with cardiac tamponade?

Background Cardiac tamponade is a life-threatening compression of the heart due to increased pericardial

pressure associated with the accumulation of fluid, solid or gas in the pericardium. In patients with hemodynamic instability, fluid boluses could maintain systemic venous return, correct hypovolemia and prevent right ventricular diastolic collapse despite very high right atrial pressure [89]. The latest European Society of Cardiology guidelines recommend volume resuscitation in the management of cardiac tamponade and discourage the use of vasodilators and diuretics (recommendation IIIC) [90]. However, data to support this strategy are limited.

Summary of evidence Four studies (1 animal, 3 human) were identified [13–16]. The human literature included 88 patients who received intravenous fluid boluses (NaCl 500 mL). Fluid boluses induced either no significant improvement in hemodynamics [91], or an improvement in blood pressure and cardiac output [92, 93]. However, only 47% of patients were fluid responders (i.e., increase in cardiac index > 10%), while the cardiac index remained unchanged in 22% and decreased in 31%; predictors of a favorable response were low systolic blood pressure and low cardiac index at baseline [92]. If fluid administration is chosen in this setting, its effects should be monitored and it must not delay pericardial drainage, even in cases of low-pressure cardiac tamponade [94].

Recommendation The panel recommends (ungraded best practice statement) that in adult patients with circulatory failure due to cardiac tamponade, fluid should be given cautiously as a temporary measure until definitive management can be undertaken.

Unresolved questions and research gaps Overall, there is insufficient evidence to support a systematic liberal or restrictive intravenous fluid strategy in patients with obstructive shock due to tamponade. The volume of fluid required to stabilize patients with obstructive shock due to tamponade while awaiting pericardial drainage is still unknown. Future studies should assess both the efficacy and the tolerability of fluid management strategies tested in this setting and identify hemodynamic profiles with the best risk–benefit ratio. They should also compare fluid with early vasopressor therapy to maintain arterial pressure.

Left-sided cardiogenic shock

Question 9

Should a restrictive or liberal strategy be used for fluid resuscitation of circulatory failure in critically ill patients with left-sided cardiogenic shock? (Table 4).

Background Left-sided cardiogenic shock is a life-threatening condition characterized by the inability of the heart to pump enough blood to meet metabolic demands, leading to inadequate tissue perfusion and organ failure [95]. Unlike other types of shock, such as hypovolemic or septic shock, where fluid resuscitation is a critical aspect of treatment, the management of fluid therapy in left-sided cardiogenic shock is more complex and controversial. This complexity arises because fluid administration can exacerbate heart failure and lead to pulmonary edema, further complicating the patient's condition [96].

Summary of evidence Fluid management in patients with left-sided cardiogenic shock remains an area of considerable uncertainty in clinical practice [95, 96]. Although the primary goal of fluid administration is to improve cardiac output and oxygen delivery by increasing preload, it may also increase left ventricular filling pressures and worsen pulmonary congestion, particularly in patients with cardiogenic shock. The available literature suggests that although some patients with cardiogenic shock may benefit from a cautious fluid challenge [97], the high risk of inducing or worsening pulmonary edema precludes widespread use of this strategy as an initial measure in the hemodynamic resuscitation of patients with cardiogenic shock [96].

A tailored approach may be recommended, where fluid therapy is not applied universally but considered on a case-by-case basis. In some cases, small fluid challenges

Table 4 Summary of the clinical question and recommendation for left-sided cardiogenic shock

Question and recommendation		Recommendation strength	Certainty of evidence
Question 9	Should a restrictive or liberal strategy be used for fluid resuscitation of circulatory failure in critically ill patients with left-sided cardiogenic shock?		
Recommendation:	*In adults with circulatory failure due to left-sided cardiogenic shock, the panel recommends (ungraded best practice statement) that fluid resuscitation should not be the primary treatment*	*Best Practice Statement*	*Ungraded*
Remark	*If fluids are administered, the patient should be monitored closely, especially for pulmonary edema*		

may be warranted to improve intravascular volume, particularly if there is evidence of concurrent hypovolemia. When considered, fluid administration requires careful monitoring and individual assessment. The physiological approach to fluid administration in cardiogenic shock involves close monitoring of the patient's hemodynamic status and adjustment of fluid therapy based on the observed individual response. Advanced hemodynamic monitoring may be used in the management of fluid therapy in cardiogenic shock. These techniques may help assess fluid responsiveness and tolerance, thereby minimizing the risk of fluid overload and pulmonary edema [98].

Recommendation In adults with circulatory failure due to left-sided cardiogenic shock, the panel recommends (ungraded best practice statement) that fluid resuscitation should not be the primary treatment. If fluids are administered, the patient should be monitored closely, especially for pulmonary edema.

Unresolved questions and research gaps There is insufficient evidence to support any specific guidelines for fluid administration in patients with left-sided cardiogenic shock. Additionally, standardized definitions and criteria for fluid status, responsiveness, and overload in these patients are lacking. Furthermore, there is a need for reliable and practical methods to assess fluid status and responsiveness in left-sided cardiogenic shock as commonly used indicators like central venous pressure, pulmonary capillary wedge pressure, or echocardiography can be inaccurate, invasive, or unavailable, respectively. Therefore, more RCTs are needed to evaluate the efficacy and the safety of fluid administration in left-sided cardiogenic shock and to determine the optimal timing, the type, and the volume of fluid. Further research is also needed to develop and validate novel and non-invasive tools to monitor fluid status and guide fluid therapy in left-sided cardiogenic shock.

Acute respiratory distress syndrome

Question 10

Should a restrictive or liberal strategy be used for fluid resuscitation of circulatory failure in critically ill patients with acute respiratory distress syndrome (ARDS)? (Table 5)

Background ARDS is characterized by varying degrees of alteration in pulmonary capillary permeability and associated pulmonary edema. ARDS is frequently caused by clinical conditions associated with relative or absolute hypovolemia and hemodynamic instability requiring some degree of fluid resuscitation (e.g., sepsis, trauma, burns and thermal injury, non-infectious inflammatory syndromes) [99]. In addition, the pathophysiology of ARDS itself causes further fluid leakage from the intravascular space into the interstitium, exacerbating hypovolemia [100]. On the other hand, fluid accumulation has been associated with worsening pulmonary edema and increased mortality in patients with ARDS [38, 101–104]. Therefore, optimal fluid management in patients with ARDS and circulatory failure is challenging as clinicians must balance the need to optimize tissue perfusion with the risk of worsening lung injury [105, 106].

Summary of evidence We found no RCT specifically comparing a restrictive versus a liberal approach to fluid resuscitation in patients with circulatory failure and ARDS. There is a systematic review by Silversides et al. that analyzed the effect of a restrictive (or conservative) versus liberal fluid administration strategy in the de-resuscitation phase of patients with sepsis and/or ARDS [107]. The authors identified seven RCTs that included patients with ARDS [108–114] and found that a conservative fluid strategy was associated with an increased number of ventilator-free days and a decreased length of stay in the ICU. However, the included studies (1) were generally old (with ventilation and sedation management strategies that are no longer used today), (2) focused on the de-resuscitation phase, (3) enrolled mostly hemody-

Table 5 Summary of the clinical question and recommendation for acute respiratory distress syndrome

Question and recommendation		Recommendation strength	Certainty of evidence
Question 10	Should a restrictive or liberal strategy be used for fluid resuscitation of circulatory failure in critically ill patients with acute respiratory distress syndrome (ARDS)?		
Recommendation:	*In adults with circulatory failure and ARDS, we cannot make a recommendation about the volume of fluid administration*	*No recommendation*	*Very Low certainty of evidence*
Remark	*Future trials should focus on patients with circulatory failure and ARDS, taking into account its different subtypes*		

namically stable patients, (4) investigated complex hemodynamic management protocols that are difficult to apply in clinical practice, or (5) did not achieve a difference in fluid balance between the two groups.

The largest RCT on this topic, the Fluids and Catheters Treatment Trial (FACTT), enrolled 1000 patients with acute lung injury, including about 30% with shock at baseline (defined as mean arterial pressure < 60 mmHg or requiring vasopressors) [108]. It compared conservative and liberal fluid strategies. The study found no difference in 60-day mortality between the groups but noted more ventilator-free and ICU-free days in the conservative group. A subgroup analysis showed no significant interaction between fluid strategy and shock at baseline. A long-term follow-up suggested that the conservative group might have worse long-term cognitive outcomes [115]. A re-analysis identified two subphenotypes (hypoinflammatory and hyperinflammatory) [116] with differing responses to fluid strategies [117]. In the hypoinflammatory group, mortality was 26% with the liberal strategy versus 18% with the conservative. In the hyperinflammatory group, mortality was 40% with the liberal strategy versus 50% with the conservative. These findings suggest acute respiratory distress syndrome (ARDS) subphenotypes may require different fluid management approaches. Although the hyperinflammatory subphenotype is associated with more hypotension, implying a potentially more liberal fluid strategy in ARDS with shock, there is no RCT to support this, indicating the need for a more personalized approach.

Recommendation In adults with circulatory failure and ARDS, we are unable to make a recommendation about the volume of fluid administration (no recommendation; very low certainty of evidence).

Remark Future trials should focus on patients with circulatory failure and ARDS, considering its different subtypes.

Unresolved questions and research gaps RCTs are needed to determine the optimal fluid management strategy for patients with both circulatory failure and ARDS. Trials should include patient subphenotyping and long-term follow-up, as long-term effects of interventions may differ from short-term effects.

Conclusions

These guidelines explored the volume of fluids in adult critically ill patients with circulatory failure of various etiologies. They provide eight evidence-based recommendations (four conditional and four ungraded best practice statements) and were unable to make recommendations for two questions. Additionally, research priorities for future studies have been identified.

Supplementary Information
The online version contains supplementary material available at https://doi.org/10.1007/s00134-025-07840-1.

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Funding
Panelists received no financial incentive for their participation. In addition, no funding or input from industry was incorporated into the guidance.

Declarations

Conflicts of interest
Daniel De Backer: received remuneration from Fresenius, Baxter, Pfizer, Edwards, Philips, and has published and presented on the topic. Armand Mekontso Dessap: reports grants from Air Liquide, and Addmedica, all outside the submitted work. Sameer Sharif: supported by the McMaster University Department of Medicine Early Career Award. Jean Louis Teboul: received fees from Edwards Lifesciences and from Getinge. Manuel Ignacio Monge Garcia: received remuneration from Edwards Lifesciences, Dynocardia and Deltex Medical. Anthony Delaney: received a MRFF grant (MRFF-1200084). Other authors reported no conflict of interest.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Received: 2 January 2025 Accepted: 11 February 2025
Published online: 31 March 2025

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